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Effect of Seasonal Variations in Diet and Climatic Factors on Reproduction of the Bandicoot Rat, *Bandicota bengalensis*

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Abstract.- Monthly data for one year were collected on body size, reproduction and diet of the bandicoot rat, *Bandicota bengalensis*, from an agricultural area near Islamabad. The breeding season extended from April to September with no pregnancy in June. Body weight and size of both sexes were less during the non-breeding period. In male, testes weight, volume, diameter of seminiferous tubules with spermatogenesis and serum testosterone increased in the breeding season. Similarly in females, a significant increase in ovarian weights, size of corpora lutea and serum progesterone level was recorded during breeding period. The pregnancy rate was maximum (81.5%) in April. The average litter size was 10.6±0.5. Wheat plant consumption started in November and continued till August. By April, wheat grains constituted more than 97% of the diet. Rhizomes of *Sorghum halapense* were eaten throughout the year except for April-May and October. *Cynodon dactylon* seeds were part of the diet from July through November, peaking in August. Breeding activity was thought to be related with change of temperature while energy-rich and abundance of food played a positive role in pregnancy rate and litter size. Some suggestions on the agricultural practices and chemical methods for management of the rodent pest have also been made.

Key words: Bandicoot, rodent pest, food habits, reproduction, Pakistan.

INTRODUCTION

The lesser bandicoot rat, *Bandicota bengalensis*, is an important agricultural pest in Pakistan. Its damage to crops, reproduction, population structure and food habits in agricultural environments in India and Pakistan have been extensively studied (Wagle, 1927; Sagar, 1972; Bindra and Sagar, 1977; Chakraborty, 1977; Durairaj and Guruprasad, 1977; Greaves *et al.*, 1977; Beg *et al.*, 1977, 1979, 1980, 1981, 1983; Smiet *et al.*, 1980; Fulk *et al.*, 1980, 1981; Fulk and Akhtar, 1981; Kaur and Guraya, 1983; Khan and Beg, 1984; Khokhar, 1986; Khan, 1987; Brooks *et al.*, 1988 and Rana, 1989). The principal studies of the species living in indoor, urban environments were those of Spillett (1968), Frantz (1973) and Walton *et al.* (1978). However, this species does not inhabit urban environments in Pakistan.

Studies on breeding biology of indoor populations (Spillett, 1968 and Walton *et al.*, 1978) and of field populations (Chakarborty, 1977; Smiet *et al.*, 1980; Fulk *et al.*, 1981) showed that the rat breeds throughout the year. Cessation of breeding in winter in the populations living outdoors has been seen by Sagar (1972), Sagar and Bindra (1978), Kaur and Guraya (1983) in Indian Punjab and by Beg *et al.* (1981), Khan and Beg (1984), and Rana (1989) in central Punjab, Pakistan.

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The area sampled for bandicoot population of present study is at the northern limit of the Punjab province. It is topographically and climatically different from central Punjab and Sindh where major studies on bandicoot have been conducted. The agriculture here totally depends upon rain. The climatic factors like rainfall, average temperature mainly and photoperiod (day-length) to some extent are also different from southern croplands of the country (Atlas of Pakistan, 1981). As cessation in breeding of the bandicoot rat is evident from the studies conducted in central Punjab, the idea of present effort was to look into the possibility, if the change in climate and cropping system has any effect on the duration of this non-breeding gap. Because control measures are best applied during a non-breeding season.

The objective of present study was to see if breeding activity is correlated with environmental factors (rainfall, day-length and temperature) and diet to see which factor induce/trigger/enhance the reproduction of the bandicoot rat. The food habits study was conducted to see the alternate host food of the species when there is no grain crop available in the field. The ultimate aim was to determine a period when there is no breeding and poor quality food available in the nature when effective control measures could be applied.

MATERIALS AND METHODS

The bandicoot rats were trapped from the fields of National Agricultural Research Centre (NARC), Islamabad (33°42/N, 73°07/E) from July, 1988 to June, 1989. The habitat trapped was wheat-fallow-wheat system. Gopher-type snap traps and wire-mesh live traps (41x14x14 cm) were used for trapping. The live traps were baited with fresh potato, onion or chapatti (unleavened bread).

Approximately 10 ml blood sample was taken from each animal by cardiac puncture after light anaesthesia with chloroform. Blood was allowed to clot and the serum was taken after centrifugation and stored at -15°C. Animals were then killed with chloroform and weighed (to 0.1 g), measured (to 1 mm), sexed and nacropsied. In females, the condition of the vaginal orifice (perforate or not), condition of the uterus (nulliparous, parous, pregnant, placental scars), condition of ovaries (corpora lutea visible or not), number of embryos and their crown-rump length were noted. In males, we recorded, whether tubules in the cauda epididymis were visible or not. The testes and ovaries were removed, cleaned off the fat and weighed (to 0.01 g). The length and width of the right testis were measured (to 1 mm). Portions of testes and ovaries in full were fixed in Bouin's solution, embedded in paraffin wax and sectioned at 6 μm thickness. Tissue sections were stained with Harris's hematoxylin and counter-stained with eosin.

Cytometric measurements of cross sections of corpora lutea and seminferous tubules were taken by calibrated ocular micrometer. Diameter were calculated by the method described by Sahu (1984). Calculated the testes volume from the length and width measurements.

Serum progesterone and testosterone levels, in females and males respectively, were measured by radio-immunoassay (RIA), using commercial kits (Amerlex-M Progesterone kit, Amersham International; Coat-A-Count total testosterone kit, Diagnostic Products Corporation).

The mean monthly values of daily minimum and maximum temperature, day length and total monthly rain fall were obtained from the Meteorological Observatory, NARC, Islamabad.

The females which showed visible corpora lutea and the males which showed visible tubules in the cauda epididymis were defined as sexually mature/aduts. Alongwith these factors, body size and weight were also considered to determine the age of the individuals. Because, cauda epididymal tubules may not be visible in a non-breeding adult male and copora lutea may not be present in an adult female during the non-breeding season which is quite long in the area in which the present study was carried out.

Stomachs of snap-trapped animals were removed for food habits studies. A reference collection of plants was made from all those found in the areas where rats were captured. Plants were identified from herbarium specimens. Four slides were made of the contents of each stomach according to the procedure described by Williams (1962) and Ward (1970). Ten fields from each of these slides were examined under X 100 and the fragments in each field were identified by comparison with similarly prepared reference slides for species of plants collected in the area.

Data were analysed using one factor Analysis of Variance and Duncan's Multiple Range tests by computer programme MSTATC.

RESULTS

Climatic factors

Monthly fluctuations in both minimum and maximum temperatures, day length and rainfall during the study period are given in Fig. 1. Temperature varied from 1.7°C in January to a mean maximum of 38°C in June. Both mean maximum and minimum temperatures fell steadily during the first 7 months of the study, then rose during the next 5 months. Rainfall was highest in July (71.8 cm) and very little in April (0.6 cm), May (0.7 cm) and November (zero). Day length was shortest in December and longest (14 h 25 min.) in June.

Body weight and size

Monthly changes in body weight and body size of adult male and female (for BW non-pregnant only) rats are given in Tables I and II. The mean body weights and size of both sexes were minimum ($P<0.05$) from November to February. Both of these parameters were significantly high ($P<0.05$) during March through October than rest of the period.

Reproduction

Testis weight and volume were lowest ($P<0.05$) from October through February. The weight increased to its maximum ($P<0.05$) in April-May and July-August and in June it decreased significantly ($P<0.05$). But the June weight was greater ($P<0.05$) than those recorded in October through February. Testis volume remained at its maximum ($P<0.05$) from April-May and in June showed non-significant ($P>0.05$) decrease and then decreased ($P<0.05$) gradually upto September. The diameter of seminiferous tubules decreased markedly ($P<0.05$) in October to March then increased until reaching at maximum ($P<0.05$) in July. The diameter

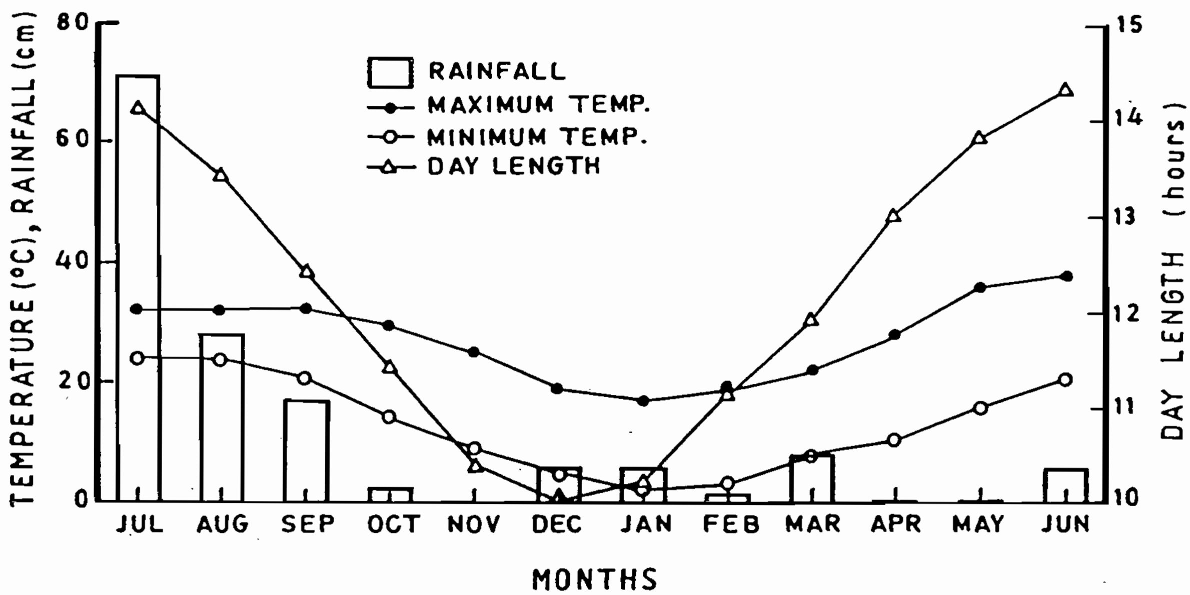

Fig. 1. Monthly variation in the climatic factors.

Table I.- Monthly changes in body size, body weight, testes weight and volume, tubule diameter and serum testosterone level in adult male bandicoot rats ($\bar{X}$±SE).

Months	N	Body Size HBL (mm)	Body Weight (g)	Testes weight/100 g BW (g)	Testes Volume (ml)	Tubule diameter (um)	Serum Testosterone level (n mol/l)
July	5	197.2±8.6BC	220.9±27.7C	0.40±0.04BC	0.94±0.13BC	222.8±5.9A	1.60±0.34AB
August	21	187.6±2.9CD	206.1±13.8C	0.45±0.02AB	0.83±0.07C	195.8±6.3BC	1.72±0.89A
September	19	192.5±3.8BC	200.2±11.5C	0.32±0.03DE	0.58±0.06D	182.3±5.1CD	1.37±0.55ABC
October	16	194.3±3.6BC	231.4±12.9C	0.20±0.02F	0.43±0.07E	142.0±4.5F	0.45±0.27BC
November	19	174.8±4.2E	149.4±11.3D	0.28±0.03E	0.23±0.03FG	143.3±5.5F	0.41±0.19BC
December	13	177.1±5.1E	141.1±11.8D	0.14±0.02G	0.17±0.03G	96.3±4.2G	0.42±0.10BC
January	12	179.2±4.8DE	161.0±11.8D	0.11±0.01G	0.16±0.02G	99.7±3.7G	0.35±0.12C
February	9	174.1±8.2E	149.1±16.7D	0.22±0.03F	0.33±0.08EF	167.5±5.3E	0.38±0.13C
March	11	200.2±6.8B	230.4±17.5C	0.36±0.02CD	0.83±0.13C	166.3±5.4E	1.05±0.34ABC
April	21	199.9±2.1B	228.4±7.4C	0.47±0.02A	1.10±0.13A	199.3±4.3B	1.87±0.56A
May	12	210.7±3.3A	275.4±11.6B	0.41±0.03BC	1.10±0.06A	187.3±5.0BCD	0.99±0.31ABC
June	6	219.5±3.8A	321.2±16.4A	0.34±0.04D	1.07±0.12AB	178.8±4.2DE	0.81±0.20ABC

Values in each column followed by the same letter are not significantly different at 5% level of Duncan's Multiple Range test.

was lower ($P<0.05$) in June as compared to breeding months (Table I). Active spermatogenesis was seen from March to October, with all stages of spermatogenesis present. In November and February we saw a recrudescent phase, showing renewed spermatogenic activity with multiple rows of spermatogonia. Marked regression in spermatogenesis in December and January was observed but, even so, late spermatid could be seen in some regions of the seminiferous tubules.

Monthly changes in serum levels of testosterone are given in Table I. It was highest ($P<0.05$) from March to September. Then it decreased ($P<0.05$) from October to December. The level remained minimum ($P<0.05$) in January and February.

Mean paired ovarian weights, diameter of corpora lutea and serum progesterone level of adult females are summarized in Table II. The ovarian weight was maximum ($P<0.05$) in April and August, and minimum ($P<0.05$) in October through March samples. The

Table II.- **Monthly changes in body size, body weight (non-pregnant), diameter of corpora lutea and serum progesterone level in adult female bandicoot rats ($\bar{X}$±SE).**

Months	N	Body size HBL (mm)	Body weight (g)	Paired ovarian weight (mg)	Diameter of Corpora lutea (um)	Serum progesterone level (ng/ml)
July	9	177.6±6.6C	174.7±41.7D	33.0±2.9B	823.8±19.0B	4.95±1.94B
August	28	192.3±2.0AB	207.3±8.0BC	60.7±7.6A	849.8±82.2B	41.64±9.84A
September	19	189.9±3.5B	198.5±7.6CD	21.7±1.6CD	488.7±40.4C	2.54±0.59B
October	21	193.5±2.0AB	208.7±8.5BC	17.9±1.9DE	499.5±38.2C	2.41±0.54B
November	19	165.3±3.7D	121.6±10.0E	11.4±0.6DE	307.5±40.5DE	2.83±1.35B
December	16	173.4±5.3CD	129.4±9.9E	11.7±1.8DE	254.3±40.7E	3.19±1.53B
January	8	183.9±6.4C	139.9±12.0E	10.0±1.1E	224.2±35.2E	3.41±0.88B
February	11	172.6±5.4CD	129.6±13.2E	12.8±2.1DE	232.0±14.9E	3.17±0.82B
March	10	186.6±6.5B	199.0±20.8CD	16.5±2.2DE	289.5±36.5CD	3.40±0.66B
April	27	201.3±2.3A	233.2±31.0AB	51.6±4.7A	986.0±72.0A	47.07±14.72A
May	13	199.9±4.5A	204.9±11.7BC	39.2±4.7B	1015.5±77.1A	15.73±6.01B
June	11	192.9±9.5AB	243.6±23.6A	30.8±2.9BC	519.6±52.8C	1.76±0.43B

Values in each column followed by the same letter are not significantly different at 5% level of Duncan's Multiple Range test.

weights were almost equal ($P>0.05$) from May to July with a non-significant ($P>0.05$) decline in June. Size of corpora lutea was minimum ($P<0.05$) during the coldest months (December to February) of the year. The size was maximum ($P<0.05$) in April-May followed by July-August. The size was significantly reduced ($P<0.05$) in June which was equal ($P>0.05$) to those of September-October. The serum progesterone levels in female rats remained almost equal ($P>0.05$) throughout the year with a sharp increase ($P<0.05$) in April and August.

The prevalence of pregnancy in adult females is given in Table III. Found two periods of reproductive activity, one in April-May, the other in July through September. No pregnant animals were found in October through March. Also, during June no pregnancies were seen. The pregnancy rate was highest (81.5%) in April, followed by 55.6% rate in August. Litter size varied from 11.7 in April to 9.3 in August (Table II). Average litter size 10.6±0.5 (48).

Dietary composition

Monthly percentage composition of various food items in the stomachs of the bandicoot rats are given in Table IV. Consumption of wheat plants started in November shortly after sowing and continued upto August. Feeding began on vegetative parts of wheat, especially the leaves, in November and December. Wheat became increasingly important in the diet as the crop growth stages moved from tillering through booting and into panicle formation in March. Peak consumption of wheat occurred in April, May and June (97.7% of the dietary mass) when wheat grains were mature. Wheat continued to be eaten following harvest, indicating that rats were feeding upon hoarded stocks.

Table III.- **Visible pregnancy and litter size in adult female bandicoot rat.**

Month	No.	No. & (%) visibly pregnant	Litter size ($\bar{X}$±SE)
July	9	5 (55.56)	9.8±0.6AB
August	28	12 (42.85)	9.3±1.1B
September	19	4 (21.05)	10.0±1.2AB
October	21	-	-
November	16	-	-
December	13	-	-
January	8	-	-
February	11	-	-
March	10	-	-
April	27	22 (81.48)	11.6±0.7A
May	13	5 (45.45)	9.4±1.2B
June	11	-	-
Totals/means	**186**	**48 (25.81)**	**10.5±0.46**

Values in last column followed by the same letter are not significantly different at 5% level of Duncan's Multiple Range test.

Table IV.- Monthly percentage composition of different food items in the stomachs of bandicoot rat.

Month	No.	Wheat Reproductive parts	Wheat Vegetative parts	*Cynodon dactylon* (Rep.)	*Sorghum halapense* (Rhizomes)	Un-identified
July	7	52.4	-	21.9	23.7	2.1
August	9	3.1	-	90.2	6.8	-
September	8	-	-	70.9	26.9	2.2
October	5	-	-	33.5	66.5	-
November	11	-	15.5	9.7	74.8	-
December	8	-	4.6	-	94.9	0.5
January	8	-	41.5	-	58.5	-
February	8	-	49.4	-	50.6	-
March	5	-	71.0	-	29.0	-
April	11	97.2	-	-	1.2	1.6
May	8	100.0	-	-	-	-
June	8	95.6	-	-	4.4	-

Values in last column followed by the same letter are not significantly different at 5% level of Duncan's Multiple Range test.

The other major component of the diet was weedy grass, *Sorghum halapense*, common on the NARC campus. It remained the part of the diet throughout the year except in May. It was observed from reference slides that the rhizomes of this grass are saturated with starch granules. During November and December, *S. halapense* rhizomes were 87.7% of the diet. There was an inverse relationship between the consumption of wheat and *S. halapense* from November to March. Another weed and common grass *Cynodon dactylon*, was the third dominant food item found from July until November. The reproductive parts of *C. dactylon* were eaten from July through November making significant part of the diet in August and September.

DISCUSSION

Body weight and size of bandicoot rat were generally lighter and smaller from November to February than in other months of the year. Both males and females were heavier and larger from March through October. In these months temperature was high, day-length was optimum/maximum and ample grain food was available in the form of wheat grain and *Cynodon* reproductive part which may have favourable effect on growth of the animals. Photoperiod and temperature have been suggested as controlling the growth of rodents (Sealander, 1966; Iverson and Turner, 1974; Petterborg, 1978). These factors also control the growth of plants hence improve the abundance and quality of food. Dietary conditions may also play an important role, as reported by Jain (1970) and Parakash (1972). Simple aging and growth of the fall survivors may also account for observed increase. In a number of species, very slow growth in winter represents a direct saving of energy, perhaps allowing more energy for thermoregulation (Stebbins, 1976). The data on body weight from Ludhiana, Indian Punjab (Kaur and Guraya, 1983), are similar to those present here. In central Punjab, Pakistan, Rana (1989) found the heaviest and largest animals in spring sample.

There was a cessation of breeding for 6 months, from October through March, which is the longest ever reported for the bandicoot rat in the sub-continent. This period corresponds to the time when day length was shortest and daily minimum temperature was lowest. Both testosterone and progesterone levels dropped to low during this time, especially the hormone level in females. The ovarian weights and diameters of corpora lutea showed a close correlation with the progesterone levels. The weight and volume of the testes also showed a significant decline during the non-breeding season.

The cessation in breeding of the bandicoot rat living outdoors was also seen by Sagar (1972) and Sagar and Bindra (1978) (January and February); by Kaur and Guraya (1983) (mid-October until mid-February) in Indian Punjab and by Beg *et al.* (1981) and Khan and Beg (1984) (November through February); Rana (1989) (December-February) in central Punjab, Pakistan. Studies on breeding biology in indoor populations in

India and Burma (Spillett, 1968 and Walton *et al.*, 1978) and of field populations in West Bengal, India and lower Sindh, Pakistan (Chakarborty, 1977; Smiet *et al.*, 1980; Fulk *et al.*, 1981) showed that the rat breeds throughout the year with out any cessation. Both of these areas are near the sea coast where winter is not severe. It seems reasonable to assume that photoperiod does not have any significant role in cessation/onset of breeding, as day-length is almost equal at all the locations in India and Pakistan where bandicoot studies (indoor or field) have been conducted so far. It looks possible that it is the change in temperature which favour the cessation/ onset of breeding. As we move toward the north the winters become severe/longer and in the present location the winter extends from November to March. While in Central Punjab, Pakistan, winter is in December through February. Apparently, start of cessation in the breeding correspond exactly to the end of the rainy season but effect of rainfall did not match with the end of breeding season. So the relationship of rainfall with breeding activity is not understood.

In the present study the rats started eating green wheat leaves from November, which increased to a considerable proportion of the diet by March. Apparently, it did not affect breeding activity until March. Breeding of rodent species in arid and semiarid regions is often associated with the ingestion of green vegetation (Chew and Butterworth, 1964; Beatley, 1969; Bradley and Mauer, 1971; Van de Graaff and Balda, 1973; Reichmann and Van De Graaff, 1975). Several species of herbivorous rodents use the secondary plant compound 6-methyoxbenzoxazolinone (6-MBOA) to trigger their reproductive activity (Berger *et al.*, 1981; Sanders *et al.*, 1981; Korn and Taitt, 1987; Negus and Berger, 1987). However, Korn (1989) found no obvious response of wild population of deer mouse (*Peromyscus maniculatus*) in terms of start of breeding season to 6-MBOA. Similarly, *Mus musculus* also did not need any green matter for breeding (Bronson, 1979). In April, wheat grains were at milky and near the maturity stage. This coincided with the maximum pregnancies and the largest litter sizes. Another peak in pregnancies occurred in August, when the diet consisted of *C. dactylon* seeds and hoarded wheat grains. It appears that breeding in the bandicoot rat responds to the availability of energy-rich food. Similarly, in rice fields of lower Sind, bandicoot rats showed great fluctuations in the prevalence of pregnancy which was related to the availability of grain food (Fulk *et al.*, 1981), while rats in the same area living in sugarcane fields did not show any sharp peaks in pregnancies (Smiet *et al.*, 1980). Khokhar (1986) observed that availability of rice and wheat grains of harvest stages exerted a great influence on reproduction of bandicoots. Khan and Beg (1984) documented a peak in pregnancies occurring during ripening and harvesting of the wheat crop. Chakraborty (1977) in India reported pregnancy peaks in bandicoots at rice harvest or shortly after.

Litter size found in the present study was maximum at the start of the breeding season. Seasonal variations in the size of litters could be due to a variety of factors (age of females, lower rat densities, first pregnancies of the season) but the observed variations mainly were related to availability of energy-rich, high protein, food. Fulk *et al.* (1984) found that in rice fields of lower Sind, the bandicoots heavily depended on maturing rice grains and responded to this diet by producing many large litters. Khan and Beg (1984) reported that bandicoots seemed to depend upon the wheat crop during spring season to produce larger litters. Rana (1989) attributed larger litters to ample food in the wheat fields during the spring season in central Punjab.

The cessation of breeding in June was evident. No significant morphological changes took place in the reproductive organs of males, while ovarian weights and corpora lutea diameters decreased in females beginning in May and reached lows in summer in June. Testosterone levels in males decreased in May and June from the April peak, then again climbed in July and August. In females, progesterone levels dropped in May and reached their lowest level in June. These changes took place although energy- and protein-rich foods were available. The assumption that the maximum day length and very high temperature could be responsible for the breeding inactivity in June cannot be implied, because, still higher temperature in Central Punjab (Pakistan) do not induce complete reproductive inactivity. Mean maximum temperature in June exceeded those of July, August and September by about 4-5°C whereas Day length in July and June were comparable. Perhaps intensive breeding in April-May lead to physiological exhaustion of the females. Possibly the June sample of adult females was not large enough to detect relatively low prevalence of pregnancy. However, this decrease in breeding activity was also reported by Kaur and Guraya (1983) in Ludhiana, India.

It is evident from the present study that breeding activity of the lesser bandicoot rat is directly related to the changes in temperatures. The females did not breed in any of the months during which the mean minimum temperature was below 15°C. During reproduction quiescence, which lasted from October through March, the rat mainly ate rhizomes of *S. halapense* and vegetative parts of wheat plants, whereas during the period of reproductive activity wheat grains and reproductive parts of *C. dactylon* were the main constitutents of the diet. So low temperature and low quality food during October-March might have been the cause of reproductive inactivity. The availability of high-energy, protein-rich food seemed to stimulate reproduction by affecting the prevalence of pregnancy and litter size.

The study suggests some agricultural practices that could reduce rodent problem. The common weed, *S. halapense* not only reduces wheat yield by directly competing with wheat pants but also is an important food source for overwintering *Bandicota*. Control of this weed can reduce rodents. Cleaning wheat fields by ploughing and burning immediately after harvest would reduce the amount of scattered wheat panicles available as rodent food and would destroy *Bandicota* burrows which may contain wheat caches. Keeping wheat fields, fallow fields and bunds free of weeds would also reduce the rat population.

Chemical control should be very effective before planting of wheat crop when the population is reproductively inactive. If sustained baiting is done in the period from October to February, when the rats are not breeding and no grain food is available, the economic returns will be high because the rat population should remain low until the following April.

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